Taste breaking with Highly Improved Staggered Quarks: Do we understand the continuum limit?

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for ABGJMP

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- ABGP (now ABGJMP) work on HVP connected part in progress
  adding $144^3 \times 288$ MILC ensemble with lattice spacing 0.042 fm
  work in progress, nothing to report yet – see Vaishaki Moningi's talk at Lattice 2025

- ABGJMP (and Fermilab/HPQCD/MILC) use staggered fermions with HISQ improvement
  Gauge configurations from the MILC collaboration

- Continuum limit with staggered fermions is not trivial:
  How should we extrapolate to the continuum limit?

- Here: taste breaking puzzle

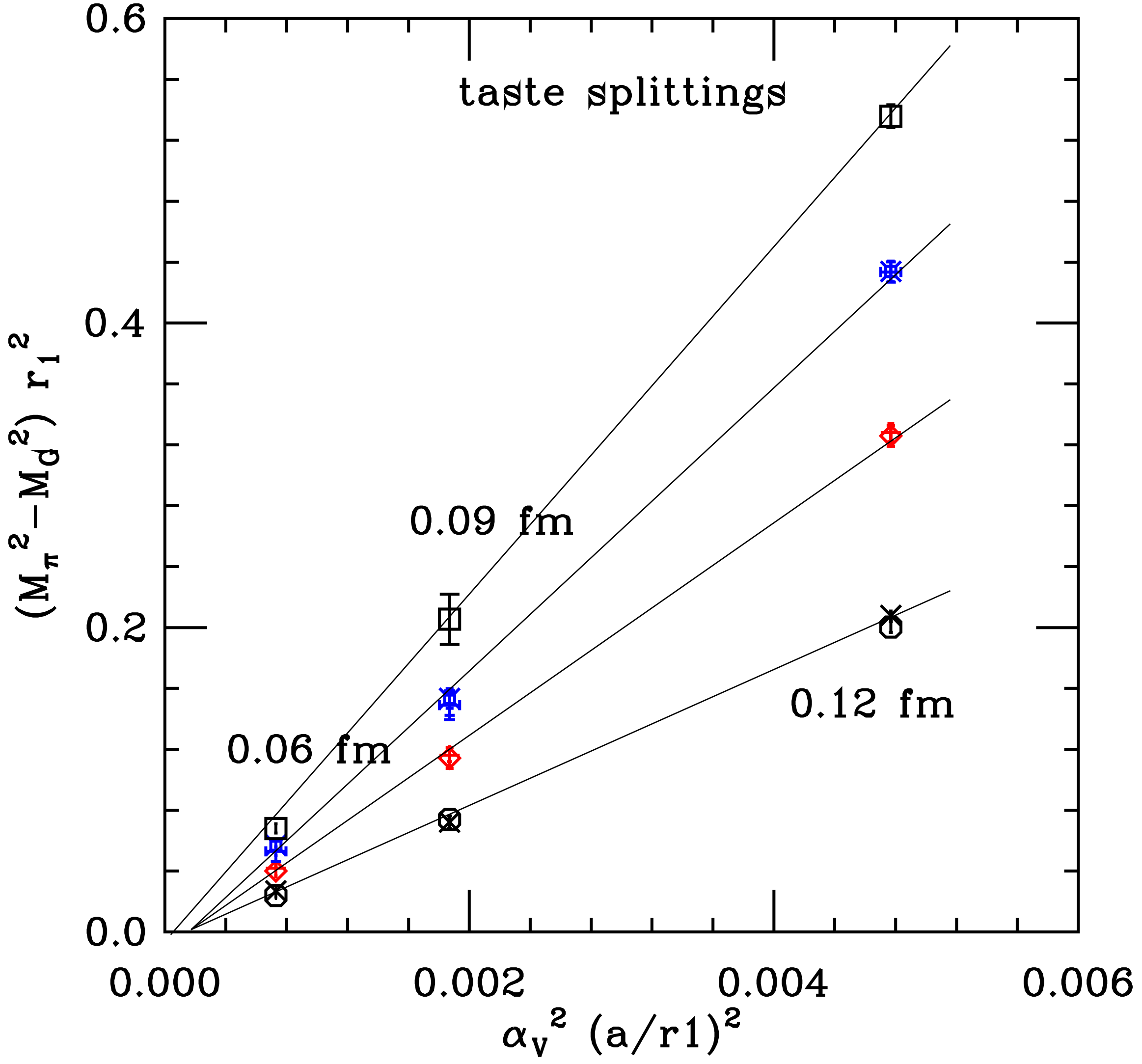
Prediction of staggered ChPT (Lee & Sharpe, '99):

- Each staggered fermion produces multiplet of 4 ``tastes" in the continuum limit – SU(4) symmetry
  On the lattice SU(4) taste symmetry is broken to a discrete subgroup
  continuum limit has SU(4) symmetry, pions in 15+1 of SU(4)
  lattice breaks this to 4 × 1 + 4 × 3 (irreps of lattice rest-frame group RF)

- To order a^2 pion spectrum organized by irreps of SO(4): P(1) + A(4) + T(6) + V(4) + S(1)

- At order a^4 SO(4) breaks down to RF (Sharpe & Van de Water, '04)

- Close to continuum limit should see SO(4) multiplets!
  One exact Nambu-Goldstone boson: consider differences $M_\pi^2 - M_G^2$ as function of a^2



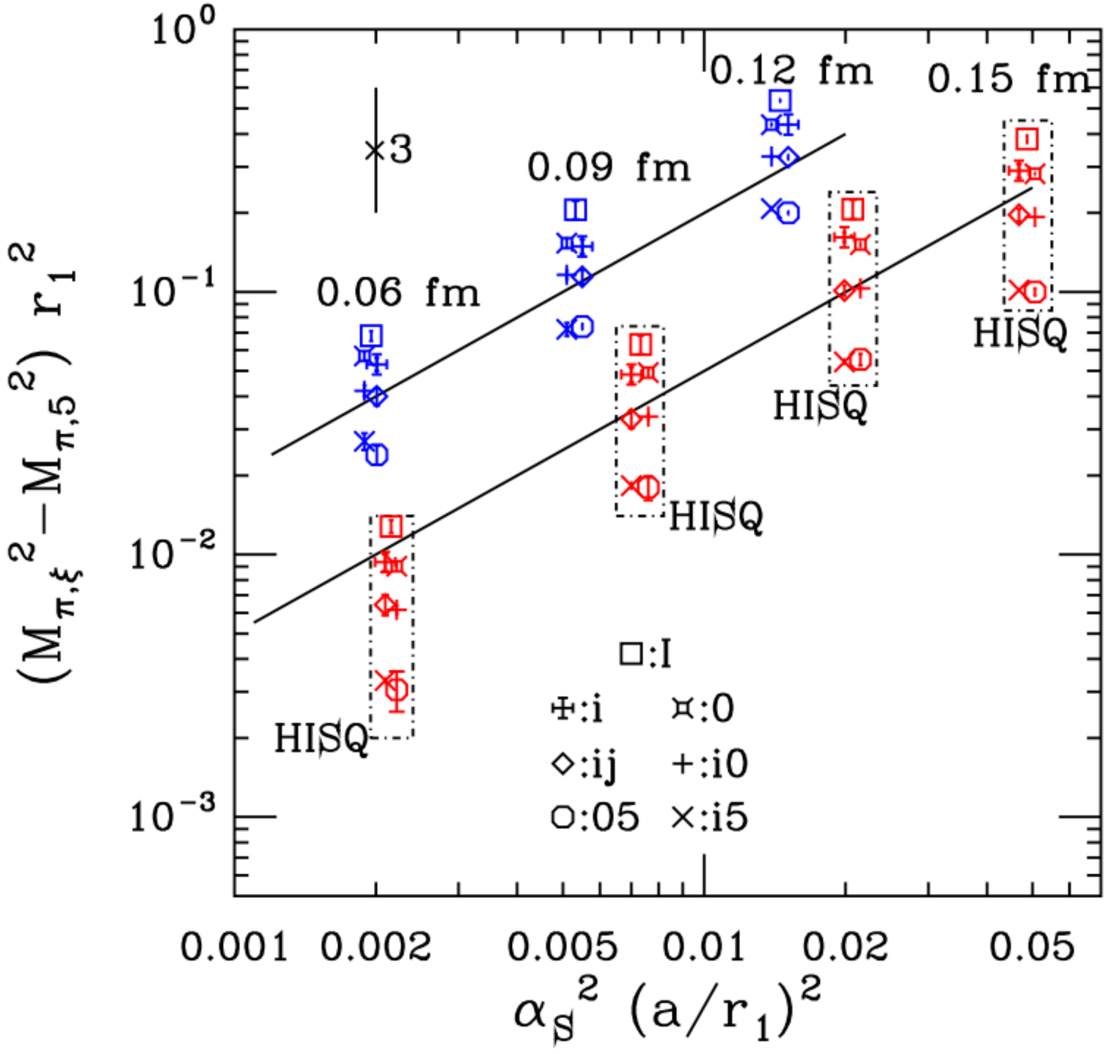
pion taste splittings with asqtad fermions (MILC '04)

top to bottom:

S
V = 1 + 3
T = 3 + 3
A = 1 + 3

straight lines by eye (not fits!) appears to work well

$O(a^2)$ prediction of SChPT confirmed

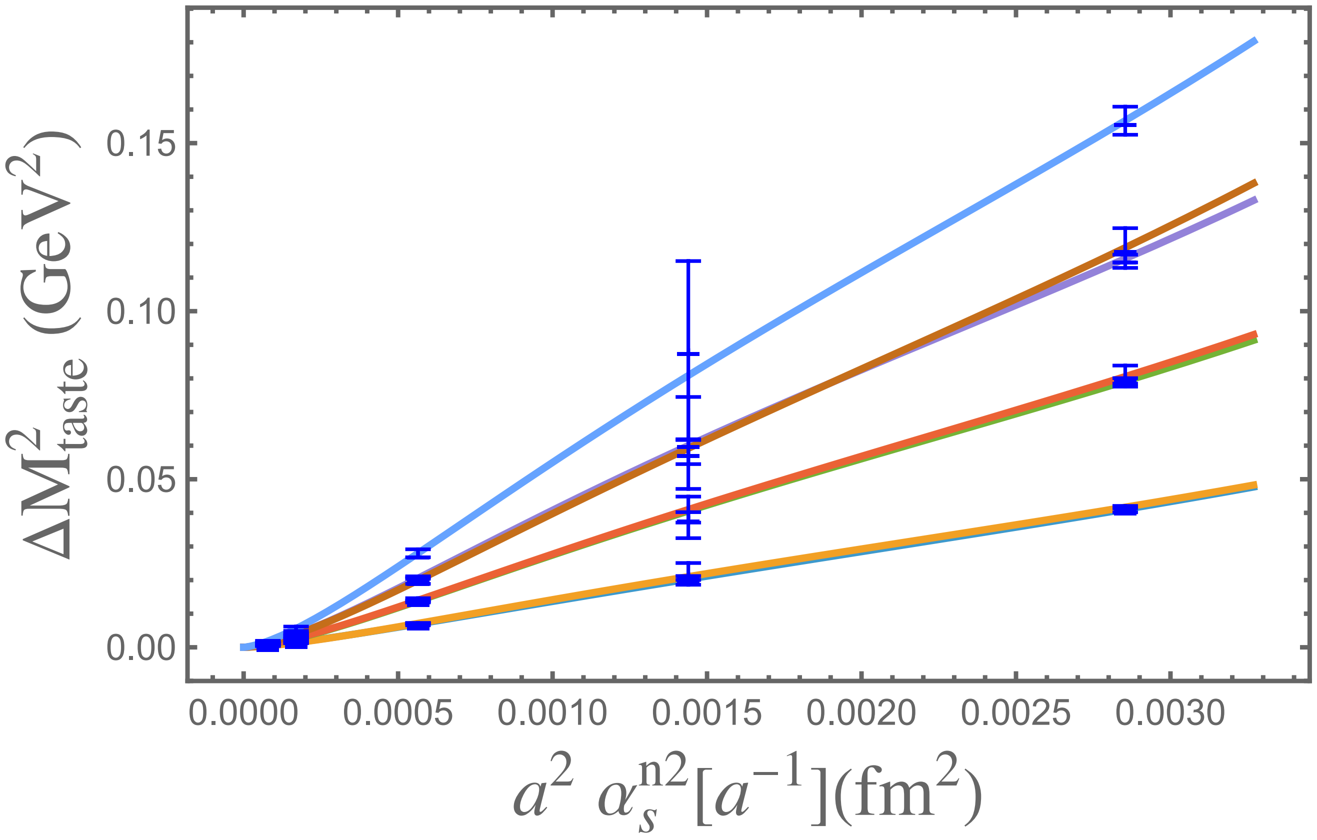


compare asqtad with HISQ
(MILC '12)

taste splitting with HISQ much smaller
@ same lattice spacing

(note: log-log plot)

degeneracies predicted by $O(a^2)$ SChPT
also present in HISQ pion spectrum



taste breaking with HISQ (MILC '12)

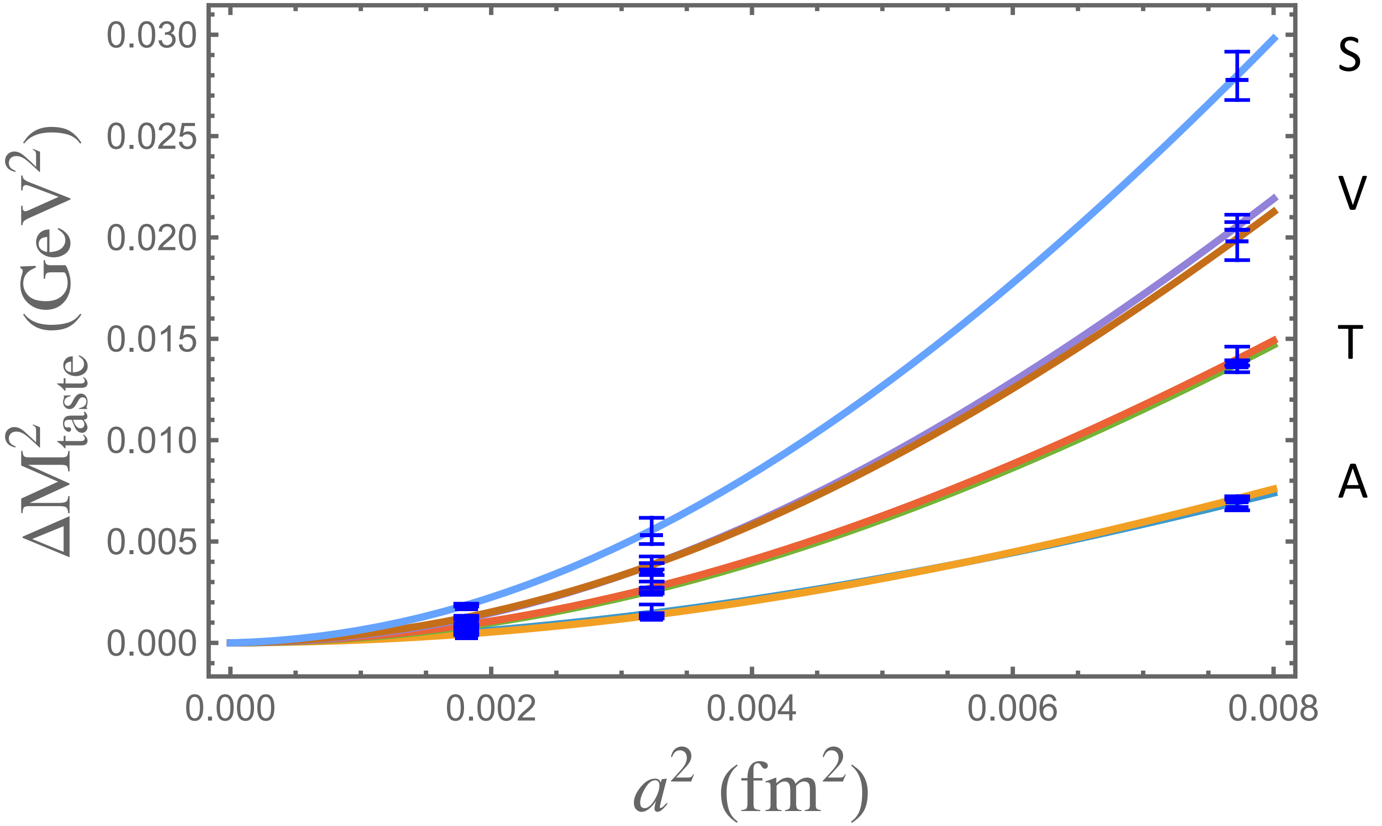
a = 0.042, 0.057, 0.088, 0.12, 0.15 fm

fit to (n2 = 2, n4 = 3, n6 = 0)

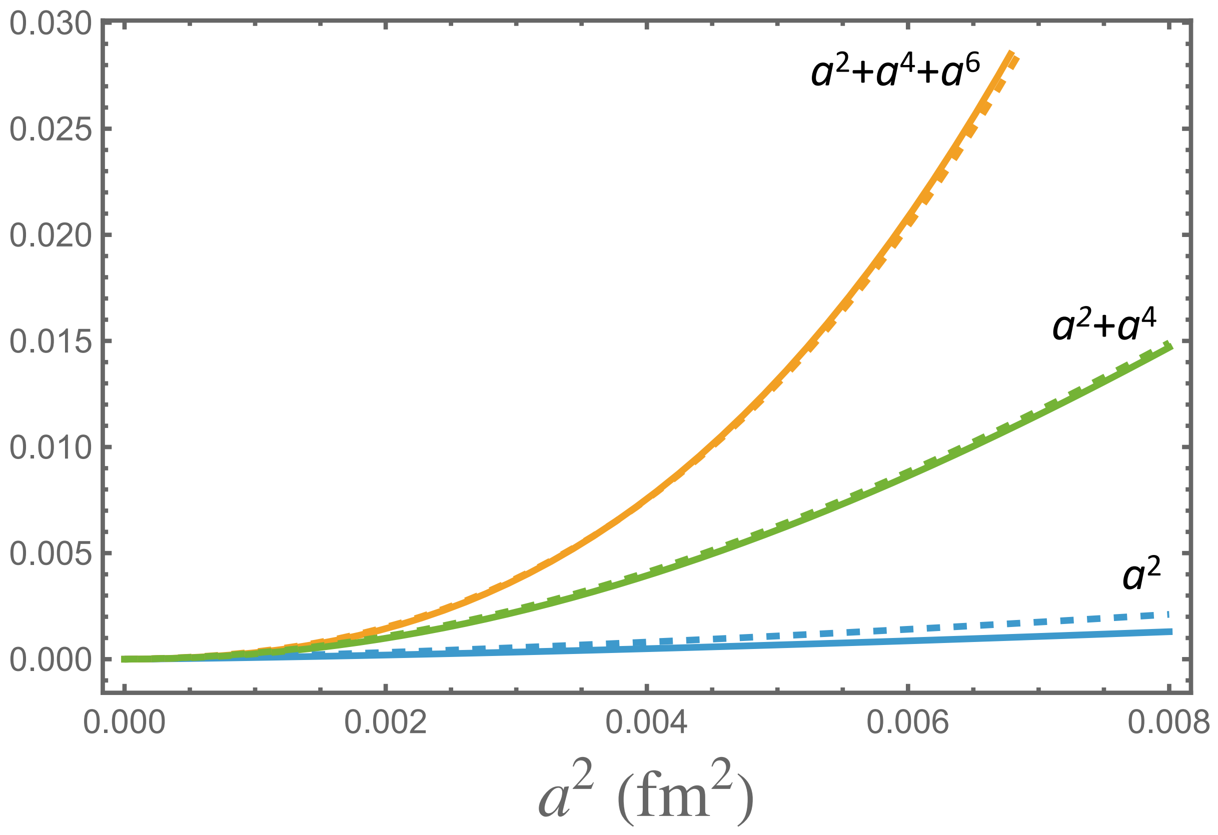
$$\Delta(\xi) = A_\xi \alpha_s^{n_2}(1/a)a^2 + B_\xi \alpha_s^{n_4}(1/a)a^4 + C_\xi \alpha_s^{n_6}(1/a)a^6$$

(too) good fit, χ^2/dof = 0.28

(caveat: no correlations)



blow up for a = 0.042, 0.057, 0.088 fm



blow up for a = 0.042, 0.057, 0.088 fm

problem:
no convergence in powers of a^2 !

shown: tensor tastes, typical

a^4 and a^6 terms dominate a^2 term

nevertheless:
approximate degeneracies
predicted by $O(a^2)$ SChPT

(cf. ABGP ’22)

- Lattice artifact – will extrapolate away in the continuum limit
  Compare extrapolations with and without taste-breaking corrections

- Still, this needs to be understood better

- MILC/Fermilab/ABGP are remeasuring taste splittings with correlations
  Work on this is in progress (Christopher Aubin and Steve Gottlieb)